Article

Low-Light Adaptation for Action Recognition-Enabled Robot Navigation

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Abstract: Effective Human-Robot Interaction (HRI) requires robots to accurately perceive and understand human actions; yet, the performance of vision-based systems degrades significantly in non-ideal, low-light environments. This limitation poses a critical challenge for applications where a robotic agent needs to navigate close to human actors in darkness, such as in emergency response scenarios. Existing solutions often rely on computationally expensive real-time image enhancement or require large, manually annotated low-light datasets, which are difficult to acquire. This paper proposes a novel and efficient data-centric approach to overcome this challenge. Instead of enhancing images at inference time, we shift the adaptation to the training phase. We introduce a synthetic low-light dataset generated from the popular COCO collection, using the CycleGAN-Turbo model for unsupervised image-to-image transformation. This synthetic dataset and the original one are then fed to the state-of-the-art AlphaPose model for pose estimation. By specializing the pose estimator for dark conditions, our method improves the 2D human keypoints detection directly from low-light video feeds. These keypoints are then formatted and passed to the MMAction2 framework for final action classification. We demonstrate through extensive experiments, evaluated with confusion matrices and keypoint score analysis, that our method improves action recognition accuracy in low-light scenarios compared to the same model trained on standard datasets. Our findings present a practical and effective pipeline for developing robust HRI systems, capable of navigating among humans in challenging lighting conditions.

Keywords: action recognition; human-robot interaction; low-light conditions; pose estimation; deep learning; synthetic data; autonomous navigation

Received:
Revised:
Accepted:
Published:

Citation: Anastasiou, M.; Bampis, L. Low-Light Adaptation for Action Recognition-Enabled Robot Navigation. *Robotics* **2025**, *1*, 0. https://doi.org/

1. Introduction

The extensive use of autonomous systems, particularly robots, in human-centric environments such as homes, workplaces, and public spaces necessitates advanced perceptual capabilities. For safe and intuitive Human-Robot Interaction (HRI), a robot must not only navigate its environment but also understand human presence, intent, and actions. The ability to recognize human actions, from simple gestures to complex activities, is a cornerstone of this understanding, enabling applications ranging from collaborative manufacturing [1] and assistive healthcare [2], to search and rescue operations [3].

While many action recognition models demonstrate impressive performance in ideal, well-lit conditions, their accuracy deteriorates drastically when deployed in the real world. Vision-based systems are particularly vulnerable to adverse lighting, such as dusk, night-time, or poorly lit indoor areas. This performance gap is a significant barrier to the